

# Frontiers in Athletic Rehabilitation: What Is Translatable to the Horse?

Sherry A. Johnson, DVM, MS, DACVSMR;  
Stephania L. Bell, PT, OCS Emeritus, CSCS;  
Lauren V. Schnabel, DVM, PhD, DACVS, DACVSMR; and  
Brian K. Noehren, PT, PhD, FACS

Authors' addresses: The Orthopaedic Research Center at the C. Wayne McIlwraith Translational Medicine Institute, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523 (Johnson); ESPN, One ESPN Plaza, Bristol, CT 06010 (Bell); North Carolina State University College of Veterinary Medicine, 1060 William Moore Drive, Raleigh, NC 27607 (Schnabel); University of Kentucky, 900 S. Limestone, Room 204D, Lexington, KY 40536-0200 (Noehren); contact e-mail: sherry.johnson@colostate.edu. © 2021 AAEP.

## 1. Introduction

The objective of this outline is to discuss emerging rehabilitative approaches used in elite human athletes, provide an overview of the research supporting their translational use, and discuss how their incorporation may apply to the equine athlete. This review follows in two sections: (A) nonoperative strategies (for use in athletes in some level of active competition or training) and (B) pre- and postoperative strategies (prehabilitation and rehabilitation for the surgical patient transitioning out of and then back into athletic workload). Appropriate incorporation of any modality or therapeutic exercise into a successful rehabilitation program relies on an accurate diagnosis. Unfortunately, universal recommendations regarding the timing, frequency, and specific indications of many of the below-described modalities are still lacking. As further research is able to define specific parameters, significant advancements within the rehabilitation field can be expected.

## 2. Translational Nonoperative Strategies

### Objectively Assessing Athletic Workload

Accurately determining the balance between appropriate training rigors and recovery to strategize the timing of peak athletic performance while mitigating risk of injury is an active area of research in human athletics.<sup>1,2</sup> This careful equilibrium not only affects in-season management, but also subsequent contract negotiation and television rights in professional human athletes. Specifically, the distinction between “overtraining” and “overreaching” has been investigated in relation to acute fatigue and markers of decreased performance.<sup>1</sup> By definition, “overtraining” encompasses an accumulation of training resulting in long-term decreases in performance capacity which may take several weeks or months to restore.<sup>1</sup> In contrast, “overreaching” refers to an accumulation of training resulting in short-term decreases in performance, which may take several days to several weeks to resolve.<sup>1</sup> Although the interplay between the two scenarios remains unclear, it is thought that overreaching precedes overtraining in a continuum of

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## NOTES

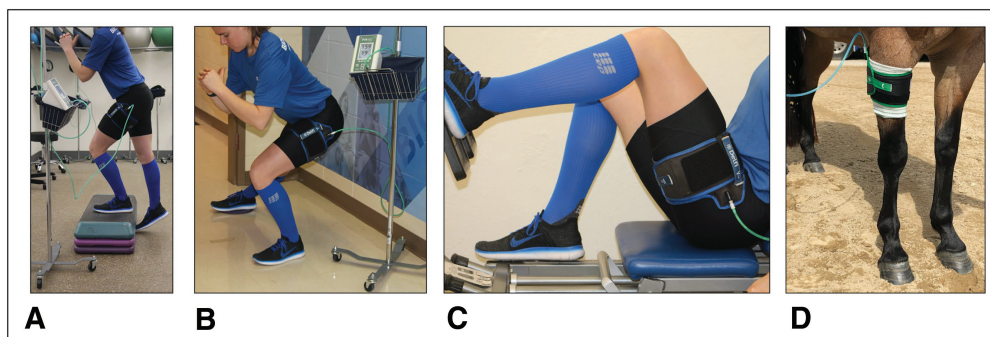


Fig. 1. Blood flow restriction (BFR) therapy applied in A, a human patient during step exercise; B, human patient during side lunges; C, a human patient during leg presses; D, an equine forelimb in preparation for walking exercise. Blood flow restriction training is being utilized by human physical therapists to prescribe controlled exercise following orthopedic injury to improve muscular strength in absence of damaging loads. Its equine applications are of current research interest. Human BFR photos courtesy of Dr. Brian Noehren. Equine BFR photo courtesy of Dr. Sherry Johnson.

symptoms. Currently implicated physiologic biomarkers associated with altered (positive and negative) exercise performance include muscle oxidative capacity, hormonal and immune measures such as neutrophils, glutamine, urea, and testosterone:cortisol ratios.<sup>3</sup> Wearable fitness tracking technology and sophisticated motion analysis software systems have also been developed to aide in early recognition of physiologic fatigue indicators (heart rate, gait parameters, for example) to further guide judicious exercise prescription. The use of Global Positioning System (GPS) technology in team sports to assess player position, velocity, and movement patterns has become integrated at the professional level with authors noting an improved ability to regulate training loads for individual athletes at crucial times of the training season.<sup>4</sup> Incorporation of such technology has even helped improve detection of signs of injury, fatigue and overtraining as injury-prediction models have continued to emerge.<sup>4,5</sup> On-body technology, however, is still considered new and evolving with simultaneous incorporation of live motion analysis described as the future iteration.<sup>4</sup>

Similarly, objective tracking performance devices to assess physiologic workload parameters have been recently developed for use in the equine athlete.<sup>6,7</sup> A recent investigation evaluated a three-axis accelerometer at three anatomic locations to determine accuracy in detecting step count and threshold acceleration values for the walk, trot, and canter.<sup>6</sup> Although equine-specific metrics to aide in interpretation of real-time data acquisition are still largely lacking, technology incorporation of such sensor use into mainstream clinical practice is expected to broaden preventative efforts associated with training fatigue.<sup>7</sup> Interdisciplinary integration into equine competition and training strategies would be facilitated by defining inherent individual variability associated with an equine athlete falling outside of “its own optimal window,”<sup>7</sup> thus solidifying individualistic approaches to maximize data interpretation that have been incorporated with human use. The utilization of validated sensor

systems to record accurate data, followed by determining the clinical significance of select measured output in horses will be the key to successful application.

#### Blood Flow Restriction Training

Low load exercise training with blood flow restriction (BFR) has become increasingly used by human physical therapists to prescribe controlled exercise following orthopedic injury.<sup>8</sup> Through application of a specialized tourniquet to temporarily reduce blood flow to an exercising limb (Fig. 1), patients are able to increase strength and muscular hypertrophy using only light weights or low-intensity exercise (cycling or walking).<sup>9</sup> In essence, BFR is being used to increase strength via low intensity training to a level typically only achieved with mid to high intensity training. Patients with a variety of physical limitations are able to safely perform BFR to improve muscle strength while protecting fragile, healing tissue from excessive loading that occurs during traditional exercise programs, thus improving physical function.<sup>10,11</sup> Blood flow restriction training is being safely used as a progressive clinical rehabilitation tool in the process of return to heavy-load exercise for a variety of human conditions including knee osteoarthritis, soft tissue injuries and geriatric sarcopenia.<sup>10–12</sup> The most consistently documented therapeutic benefits of BFR within the human literature are muscular hypertrophy and subsequent increases in strength secondary to elevated levels of growth hormone (GH).<sup>13,14</sup> The metabolic accumulation of GH has been demonstrated to reach supraphysiologic levels (290 times that of baseline) during human BFR training and is thought to be the main activator of resultant muscular hypertrophy.<sup>13,14</sup> Also noteworthy is that the use of patient-specific BFR occlusion pressures have become the standard of care in human practice due to improved comfort and minimized safety risks.<sup>15</sup>

Although numerous studies have been performed validating human BFR use with compelling results, investigations to assess equine-specific application are considerably sparse.<sup>16,17</sup> An initial pilot study

evaluated cuff application to a single equine forelimb ( $n=6$ ) using an occlusion pressure of 200 mm Hg applied only at rest.<sup>16</sup> Following three sets of occlusions for five minutes, muscle thickness was assessed ultrasonographically in addition to peak flow velocity and flow velocity integral of the radial artery. Authors noted that extensor and flexor muscle thickness was increased in the occluded limb, but not the control limb. Authors concluded that acute vascular occlusion may be safe and tolerable in horses.<sup>16</sup> Subsequently, the same research group confirmed that horses would tolerate BFR at a walk pace.<sup>17</sup> Six unfit Standardbred mares performed BFR of both forelimbs at a walk pace with 200–230 mm Hg cuff pressure once per day, 6 days per week for a total of 2 weeks. Skeletal muscle thickness and tendon thickness were assessed ultrasonographically and serum growth hormone (GH) concentrations were determined 5, 15, and 60 min following BFR exercise sessions. Authors confirmed that similar to humans, BFR use in horses resulted in elevations in GH and muscular hypertrophy. In contrast to the use of blanket occlusion methodology in the aforementioned equine investigations, a recent study describes short-term beneficial effects of BFR on equine superficial digital flexor (SDF) muscle oxidative capacity over a 10-day study period using BFR pressures based on daily readings.<sup>18</sup> Specifically, SDF muscle oxidative capacity increases were consistent with acute metabolic adaptations of increased mitochondrial density and an improved ability to oxidize fuels.<sup>18</sup> Other commonly used rehabilitation modalities such as underwater treadmill and conventional treadmill exercise, however, have failed to affect SDF muscle metabolic responses over four- and eight-week time periods,<sup>19,20</sup> suggesting that neither modality alone increases muscle oxidative capacity to the same extent as other forms of resistance training.<sup>21</sup>

Equine athletes competing with chronic injuries, recovering from orthopedic procedures and geriatric horses all represent patients with physiologic limitations to consider when prescribing exercise and strengthening programs. Blood flow restriction training may represent a strategy to optimize equine neuromuscular adaptations during extended recovery periods, but BFR cuff placement and type of exercise used thereafter is a significant application difference between humans and horses (Fig. 1). Despite these differences, however, BFR may represent a novel, medication-free bio-solution to consider in the process of return to heavy-load exercise. Its titrated use under trained professionals may augment historic exercise prescription currently limited by the presence of fragile, healing tissue and the inability to predict spontaneous overexertion in the horse. Ongoing investigations are expected that may further refine recommended use and safe practices for use in horses.

#### Contrast Therapy

Contrast therapy is defined as the application of alternating cycles of both cold and heat in a repeated

manner with the goal of increasing blood circulation through cyclic vasoconstriction and vasodilation.<sup>22,23</sup> Optimal skin tissue temperatures in humans have been documented to be 10–15°C for cryotherapy and 38–43°C for heat application.<sup>23,24</sup> A significant body of work exists within human literature investigating the effects of contrast water therapy on postexercise recovery outcomes, with conflicting results.<sup>25,26</sup> Recently, when the effectiveness of various methods of 10-minute thermal therapy (cold water immersion at 10°C, thermoneutral water immersion at 24°C and contrast water therapy alternating at 10° and 38°C) were compared using physical and mental performance measures and physiological responses, the self-perceived feeling of relaxation after 6-min recovery was significantly better after cold water immersion and contrast water therapy, leading authors to conclude it may play a positive role in athletes' performance and overall well-being.<sup>2</sup> In contrast, previous work has not documented improvements in strength and sprint performance after contrast water therapy compared to passive recovery alone.<sup>25,26</sup> Despite conflicting results, contrast therapy is being increasingly utilized by professional athletes to augment recovery strategies. Contrast therapy has technically always been available for use in the equine athlete, but historic focus has largely been on the effects of cryotherapy and superficial heating modalities used independently,<sup>27–30</sup> and its utility in equine rehabilitation remains largely unknown.<sup>22</sup> Recently, tissue temperatures at different tissue depths relative to the digital flexor tendons as assessed by thermistor placement during serial heating and cooling cycles using a human contrast therapy device<sup>a</sup> was found to consistently induce therapeutic cooling (<15°C) and heating (>40°C) of tissues to the depth of the deep digital flexor tendon (DDFT).<sup>22</sup> Interestingly, target tissues at the skin were reached within 9.5 min when heat was applied first but required up to 12.5 min when cold was initially applied.<sup>22</sup> Also noteworthy is that in the majority of limbs, tissues deep to the DDFT did not reach target tissue temperatures during the 15-min heating or cooling cycles,<sup>22</sup> obviating the limitation to significantly affect the proximal suspensory ligament's temperature. Authors hypothesized that a countercurrent temperature mechanism played a role in the inability to heat or cool tissues deeper than the DDFT compared to more superficial tissue.<sup>22</sup> Application of cold or hot thermal therapy through ice packs, water immersion, heat packs, heated blankets, etc. has certainly always been physically available to the equine clinician but having a commercially available dry-interface system that can reliably and consistently induce therapeutic tissue changes to a known tissue depth is certainly of value, with the next logical investigative step being to evaluate contrast therapy's clinical efficacy in injured tissues. Continued efforts to expand knowledge around contrast therapy's efficacious use can be expected.

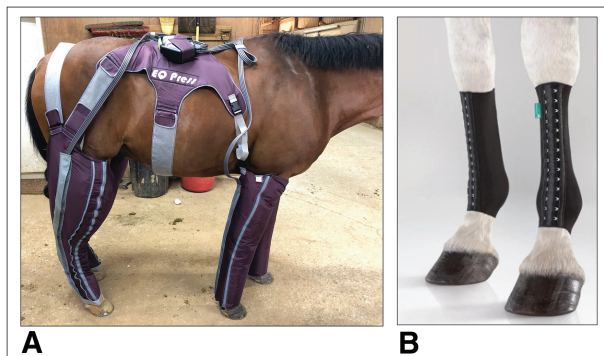


Fig. 2. Two emerging compression technologies consisting of A, Full-limb pneumatic dynamic compression device to encourage retrograde movement of lymphatic fluid. Photo courtesy of EQ Press, Vetletics Morrisville, NC; B, EquiCrown® Canada "FIT" compression sleeves. Photo courtesy of EquiCrown Canada.

#### Advances in Compression Technology

Recovery acceleration through the use of various rehabilitative strategies including stretching, massage, compression garments and combinations of the aforementioned are being increasingly used in human athletes to minimize days out of competition and speed active recovery.<sup>31</sup> Accelerating lymph circulation has been demonstrated to beneficially remove metabolic products, improve body fluid dynamics, cause changes in microcirculation and reduce venous blood return.<sup>32–34</sup> Various methods of improving human lymphatic flow include the use of mechanical stimulation, deep oscillation, and physical stimulation<sup>35</sup> but reported methodology is so varied that universal clinical practice guidelines for use in sports medicine and rehabilitation are lacking.<sup>36</sup> Nonetheless, integration of manual lymphatic drainage techniques alongside conventional rehabilitation therapies has become a mainstay of athletic physical therapy programs. Similarly, lymphatic compression technology available for use in the equine athlete includes both full and distal limb systems (Fig. 2). Although the use of compression wrapping has been in use and well tolerated by horses for decades, recent noteworthy advances include the incorporation of full limb, human-grade pneumatic compression technology<sup>b</sup> with automatic cycling that works to dynamically push lymphatic fluid retrograde in between cycles. This product shares the same manufacturer and pump system as the FDA approved human device<sup>c</sup> and is currently being investigated for the treatment of lymphangitis as well as for athletic recovery.<sup>d</sup> Distal limb compression wraps using medical-grade bandages custom-fit based on anatomic measurements<sup>e</sup> also offer the clinician an avenue through which distal to proximal pressure gradients can be maintained based on the contour of an individual horse's limb. Such systems when combined with contrast therapy, appropriate exercise, retrograde massage and titrated, supervised application have

resulted in significant clinical improvements of chronic distal limb edema/lymphedema based on serial, circumferential limb measurements.<sup>f</sup> With continued investigation of specific application parameters and correlation to performance outcome measures, further recommendations can be expected.<sup>37</sup>

### 3. Translational Pre- and Postoperative Strategies

#### Preoperative Management to Maximize Postoperative Results (Prehabilitation)

There is considerable interest in determining if the use of prehabilitation (receiving physical therapy before a human patient undergoes surgery) results in better outcomes. By performing rehabilitation before surgery, the goal is to help the patient be more prepared for the period of postoperative care that is characterized by limited physical activity, immobility, and reduced function.<sup>38</sup> The majority of the research on the effectiveness of prehabilitation in humans has centered around anterior cruciate ligament injuries (ACL) of the knee. Because of the acute nature of the injury, there is debate as to whether it is better to quickly reconstruct the ACL or wait for a period of time for the resolution of swelling, limited knee motion, pain, and muscle strength inhibition. Programs to prepare the human athlete for surgery through a physical therapy program involve several components. First is aggressive management of swelling or edema around the knee. This component of care is considered critical as swelling results in muscle inhibition, limits range of motion, and contributes to feelings of instability. However, the focus cannot entirely be on reducing swelling as the clinician must also attempt to maximize recovery by engaging the patient in exercise that does not exacerbate swelling or significant pain. Careful consideration of balancing multiple priorities i.e., regaining strength and range of motion often means having a patient use a crutch or limit too much other physical activity. Another aspect of care that is critical to address before surgery is the incorporation of exercises that focus on neuromuscular re-education. This can take the form of using electric stimulation to help the athlete learn to recruit and use the muscle again. In addition, the athlete should begin to perform exercises that excite the neuromuscular system. For ACL reconstruction rehabilitation, electric stimulation is performed over the quadriceps muscle with the intensity as high as tolerable for the athlete set to a Biphasic or Russian stimulation. The pulse duration is usually on order of 250–300 plus microseconds, with a pulse frequency of 50 Hz with the subject performing a 10-s hold during the stimulation followed by 50 s of rest. The typical duration of this treatment is 10 min. The 10-s hold followed by 50 s of rest is done to minimize fatigue. In addition, dynamic neuromuscular

control can be facilitated by having the patient work on balance training while standing on an increasingly unstable surface and/or perturbation training whereby the athlete is on an unstable surface with a physical therapist manipulating the direction and magnitude of perturbation. Lastly, during this period of time the patient typically engages in open chain strengthening of the quadriceps muscle to offset any loss of strength due to initial inhibition. Patients will train for three to four sets with a weight that will result in fatigue (i.e., failure to complete an additional repetition by the end of the third set). Typical length of these programs is anywhere from 4 weeks or in some cases 10 sessions. Each session takes the physical therapist about 60–90 min to complete with the patient. Several clinical trials and systematic reviews have been done to investigate the effect of a prehabilitation program.<sup>39–41</sup> Seminal work by Failla et al. showed that a prehabilitation program that included perturbation training resulted in a greater percentage of athletes returning to sport and having good patient reported outcomes.<sup>38</sup> In addition, Shaarani et al. incorporated a 6-wk prehabilitation program and found increased single leg hop distance, better patient reported outcomes, and a trend towards a higher percentage of Type 2 muscle fiber expression at a 12-week postoperative follow up as compared to subjects without prehabilitation.<sup>39</sup> Although results of these studies are encouraging, recent results of two systematic reviews indicate more work is needed to establish the effectiveness of such programs.<sup>40,41</sup> There remains a need for large well controlled trials to evaluate the potential benefit of such programs. However, the evidence to date is encouraging that some form of prehabilitation will better prepare an athlete for their postoperative recovery. In the equine athlete, there are many important factors for prehabilitation that clinicians have started to consider. Of critical importance, and of relevance to the psychosocial discussion below, is the importance of finding the optimal environment for the horse to thrive and recover in. Prior to surgery, the horse should ideally be acclimated to prolonged periods of stall rest as well as any bandages, garments, equipment, and exercises that will be used postoperatively. For very fit horses accustomed to working and/or turnout, stall rest can be mentally and physically challenging to them and dangerous to both them and their handlers. In some cases, moving the horse from an active show or competition barn to a quiet rehabilitation barn with all horses in stalls and on similar schedules is enough to calm an anxious horse and prevent the development of stall vices or dangerous behavior. In other cases, however, the use of long-term sedatives such as reserpine<sup>42</sup> or trazodone<sup>43</sup> are needed to facilitate calm stall rest and controlled exercise. Once the proper environment

has been achieved, there are many ways that prehabilitation for the equine athlete can be pursued, similar to what is being done for human athletes. In the authors' opinion, all horses can benefit from mobility, strength building, and core stability exercises both during the prehabilitation period and the rehabilitation period. Such exercises are well described,<sup>44,45</sup> simple to perform, and have been proven to have an effect, particularly on increasing the cross-sectional area of the multifidus muscle.<sup>46</sup> In addition, both active and passive range of motion exercises can be used preoperatively for certain injuries, to prepare the horse for rehabilitation, and to try to limit fibrosis preoperatively. Such exercises may be particularly useful for surgeries of the tendon sheath and fetlock joint where adhesions and fibrosis commonly occur. **The use of electrical stimulation in equine physical therapy for muscle activation and training is being explored and certainly warrants further investigation. A recent study examined the use of a commercially available electrical stimulation unit FES 310<sup>®</sup> applied using a back treatment pad over the sacral region to generate movement in the lumbosacral region of standing horses without known pathology.<sup>47</sup> The authors found that although the movement caused by the electrical stimulation was smaller than that caused by manual pelvic inclination, its effects were documented in a wide area including the muscles of the hind limb. In addition, the authors state that electrical stimulation could easily be applied over a longer period and in a higher frequency than is possible for manual pelvic inclination, providing justification for future studies into its use for stabilizing the sacroiliac joint and potentially for training of the quadriceps muscles.** Also similar to neuromuscular re-education in human athletes is the use of proprioceptive retraining techniques in horses. Examples of such techniques include kinesiotaping,<sup>48,49</sup> tactile stimulators,<sup>50,51</sup> and more recently equine balance pads (Fig. 3).<sup>h,52</sup>

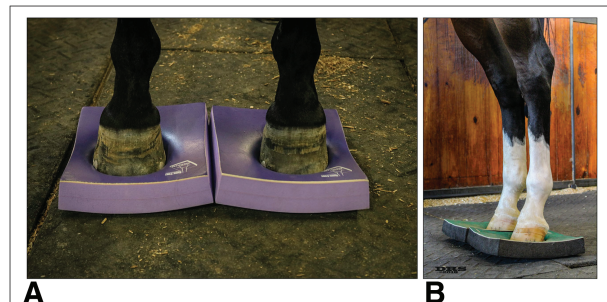


Fig. 3. Balance pad used in horses referred for professional rehabilitation. A, Bilateral forelimb application while standing on medium density (purple) Sure Foot balance pads; B, Bilateral hindlimb application while standing on firm density (green) Sure Foot balance pads. Photos courtesy of Equine Sports Medicine & Rehabilitation, Whitesboro, TX 76273.

### The Influence of Psychosocial Factors on Physical Recovery During Postoperative Care

The role of psychosocial factors is receiving increased attention for the influence they have on the physical and patient reported outcomes of human athletes after injury. Several constructs have been considered, which include self-efficacy, fear of re-injury, and psychological readiness to return to sport. Prior work has found that a more positive assessment of self-efficacy,<sup>53</sup> a lower fear of re-injury,<sup>54</sup> and feelings of greater psychological readiness to return to sport<sup>55</sup> result in higher likelihood of returning to preinjury levels as well as reduce the risk of second injury.<sup>56</sup> In addition, there is evidence to suggest that lower psychological readiness to return to sport after an ACL reconstruction resulted in the human athlete having greater deficits in their running gait in the injured knee as compared to the uninjured knee.<sup>57</sup> In addition, work from Beischer et al. shows that patients with higher knee self-efficacy at 4 months after surgery had increased odds for symmetrical muscle function at 1 year after surgery.<sup>58</sup> Clearly, psychosocial aspects of recovery are important adjuncts that must be considered during the recovery from surgery. How to best help and treat athletes who are not coping well with their recovery is also an area of active investigation. For athletes with significant postoperative challenges in coping with the response to injury referral to a sports psychologist or other mental health professional is warranted. Many athletes though do not have access to psychologists or may have an important but modest or moderate negative change in domains such as self-efficacy and fear of re-injury and not be willing to seek care. Within those cases positive supportive discussion, goal setting and engaging the athlete in the rehabilitation process are all potential adjunct therapies to consider. For example, engaging the athlete for their input on what is done in the rehabilitation program on a given day may help them feel that they have control and an active voice in their recovery process. Also, careful consideration of word choice and non-verbal behavior when interacting with human athletes can communicate a lot of how the practitioner feels about their recovery that they then internalize. In regard to the equine athlete, psychosocial factors may be relevant to both the horse themselves as well as their caretakers, trainers, and owners. Horses can certainly become "sour" or resistant to training methods, specific movements, or even pieces of tack that they associate with pain from an injury. Breaking the pain cycle of an injury is imperative to overcome the negative associations that a horse has developed. In addition, some horses seem to require a temporary, or in more severe cases, permanent change in training methods or tack for them to return from an injury and advance in their career. In the authors' opinion, pain from the axial skeleton and especially the back, can be particularly difficult for equine athletes to overcome in this regard. Horse caretakers and riders also commonly

have their own fears and other psychosocial concerns. Helping caretakers and riders by using the same processes done in human athletes such that the equine athlete is perceiving that those around them are showing positive response about how they are doing is a very interesting area to explore. Although rider fears may be of themselves getting injured or for their career, they often also have fears or concerns that the horse might still be in pain or discomfort, even if not overtly lame. The Ridden Horse Pain Ethogram (RHpE) as developed and evaluated by Dyson et al. may be very useful for such riders and for veterinarians as well.<sup>59-63</sup> In the most recent of the RHpE comprised of 24 behaviors, a RHpE score of greater than or equal to 8, meaning eight or more of the behaviors were displayed, was found to be a good indicator of musculoskeletal pain.<sup>59</sup>

### Exercise Specificity

The balance between exercises that simulate or recreate the event the human athlete has to engage in versus targeting the muscle or tissue specifically injured is an area that continues to be debated within the physical therapy community. There is clearly a need for recreating situations that the athlete may experience and training the individual neuromuscular system to respond appropriately. A series of studies by Hewett and colleagues showed, for example, that by focusing on neuromuscular training one could alter movement patterns and reduce risk for subsequent injury.<sup>64-66</sup> Further, work by Noehren et al. shows the benefits of programs such as gait retraining which emphasize the benefits of directly addressing the faulty movement mechanics using real-time visual feedback to reduce pain in patients with patellofemoral pain.<sup>67</sup> Although these individual studies are supportive of programs that focus on improving movement mechanics the studies were not designed to evaluate a comprehensive program. Clinical experience would dictate that without sufficient underlying muscle strength and control, engaging in such gait retraining programs would be detrimental to recovery. It is established, for example, that following an orthopedic injury such as an ACL tear that regaining quadriceps muscle strength predicts normalization of gait, function, self-reported outcomes, return to play and risk of developing post traumatic osteoarthritis.<sup>68-74</sup> Consequently, it is critical that as recovery progresses, loads increase to stimulate adequate muscle hypertrophy. During the early phases of healing using adjuncts such as blood flow restriction training as previously discussed may be an excellent way to slow or reverse muscle atrophy during times when other tissues such as ligaments need to be protected to fully heal. In addition, one can have the athlete use a lighter weight and exercise to the point of muscle fatigue to help stimulate the muscle. Only by carefully considering the underlying impairments and how that contributes to altered movement mechanics can one help the human athlete return to their preinjury levels of function. In addition, careful

attention to movement mechanics as the athlete progresses in rehabilitation is critical to reduce risk of reinjury and long-term complications.

#### 4. Conclusion

Novel physiotherapeutic strategies to augment healing in the equine athlete are evolving, with many modalities applicable to both humans and horses. Veterinarians should defer to specific show jurisdiction guidelines for recommended use in the actively competing equine athlete. Continued collaboration to develop, evaluate, and implement effective translational approaches will redefine historic paradigms in both human and equine practice.

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##### Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

##### Conflict of Interest

Dr. Sherry A. Johnson is a co-founder and partner of Equine Core, Inc (Fort Collins, CO), an entity that is developing equine-specific blood flow restriction devices. Dr. Lauren V. Schnabel is a co-founder of Vetletics Inc. (Morrisville, NC).

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